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Climate Services for Clean Energy

Work Package 3 Webinar

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This project has received funding from the Horizon 2020 programme under grant agreement n°776787.
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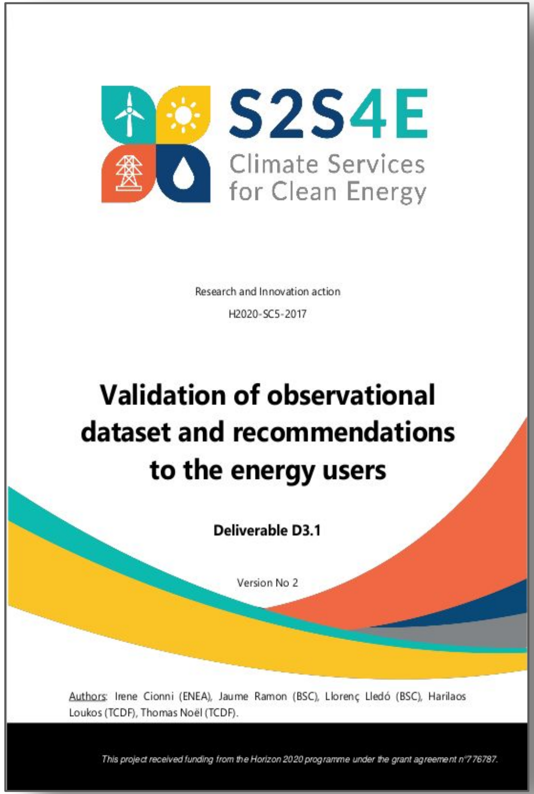
Introduction



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Research and Innovation action

H2020-SC5-2017

Validation of observational dataset and recommendations to the energy users

Deliverable D3.1

Version No 2

Authors: Irene Cionni (ENEA), Jaume Ramon (BSC), Llorenç Lledó (BSC), Harilaos Loukos (TCDF), Thomas Noël (TCDF).

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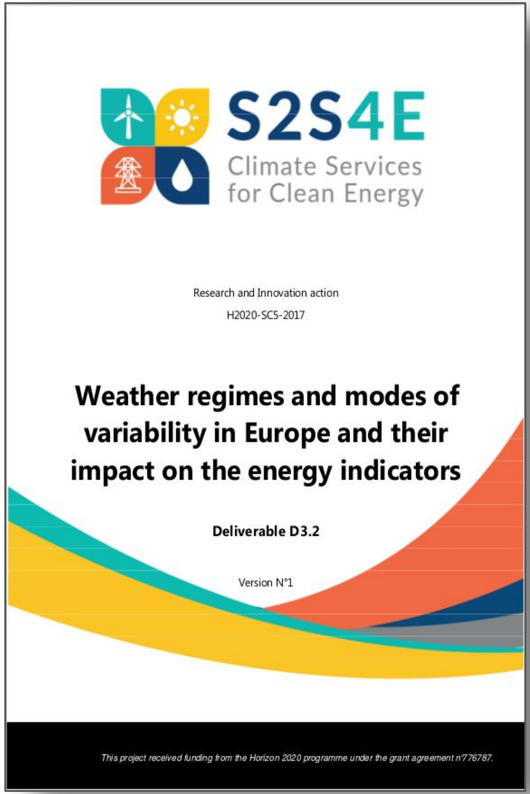

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Research and Innovation action

H2020-SC5-2017

Weather regimes and modes of variability in Europe and their impact on the energy indicators

Deliverable D3.2

Version N°1

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Reanalysis benchmarking

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Background and Motivation: Building trust

Reanalysis data sets are employed within S2S4E project for several purpose:

1) verify and bias adjust seasonal and sub-seasonal predictions;

2) derive indicators of energy indicators and demand, and

3) understand the impact of weather regimes and teleconnection indices in the electricity generation and demand.

Evaluating the quality of the available reanalysis products that will be used is key for credible conclusions.

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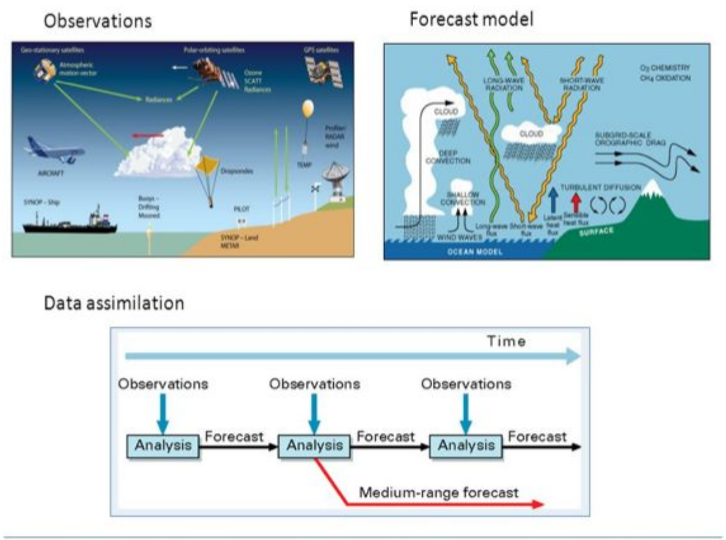
Reanalysis

Reanalysis are produced via an unchanging data assimilation scheme and model which ingest all available observations over the period being analysed. This framework provides a dynamically consistent estimate of the climate state at each time step.



Source *ECMWF*

PRO:

–Global datasets,consistent spatial and temporal resolution over 3 or more decades, hundreds of variables available.

–Milions of observations incorporated into stable data assimilation system enabling a number of climate processes to be studies.

–Datasets are straightforward to handle from a processing standpoint.

LIMITATIONS:

–Observational constraints, and therefore reanalysis reliability, can vary depending on the location, time period and variable considered.

–Possible spurious variability and trends due to the changes in the mix of observations, and biases in observations and model.

–Diagnostic variables relating to the hydrological cycle, such as precipitation and evaporation, should be used with extreme caution.

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Intercomparison of reanalysis

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Reanalysis

Reanalysis	ERA5	ERA-Interim	NCEP/DOE R2	NCEP/NCAR R1	JRA-55	MERRA-2
Producing center	ECMWF	ECMWF	NCEP/DOE	NCEP/NCAR	JMA	NASA GMAO
Coverage	Global	Global	Global	Global	Global	Global
Spatial resolution	~ 30km	~79 km	~205 km	~205 km	~55 km	~ 55km
Time resolution	hourly	6-hourly	6-hourly	6-hourly	6-hourly	hourly
Available period	1950-present*	1979-present	1979-present	1948-present	1958-present	1980-present
References		Dee et al., 2011	Kanamitsu et al., 2002	Kalmay et al., 1996	Kobayashi et al. 2015	Gelaro et al., 2017
Operational availability	Daily updates, <1 week of delay	monthly updates, 2/3 months of delay	monthly updates, <1 week of delay	monthly updates, <1 week of delay	daily updates, <1 week of delay	monthly updates, 15th/20th of next month
Commercial applications	allowed	allowed	allowed	allowed	not allowed	allowed
Employed period	2000-2017	1980-2017	1980-2017	1980-2017	1980-2017	1980-2017
Employed time resolution	daily&monthy means	daily&monthy means	daily&monthy means	daily&monthy means	daily&monthy means	daily&monthy means
ECVs	t2m,solar rad., scf wind, precipitation.	t2m,solar rad., scf wind, precipitation.	t2m,solar rad., precipitation.	scf wind	t2m,solar rad., scf wind, precipitation.	t2m,solar rad., scf wind, precipitation.

Selection of four ECVs that impact the energy sector:

–**2 meter temperature** for energy demand;
–**surface solar radiation** for solar power generation;
–**surface wind speed** for wind power generation;
–**precipitation** for hydropower generation.

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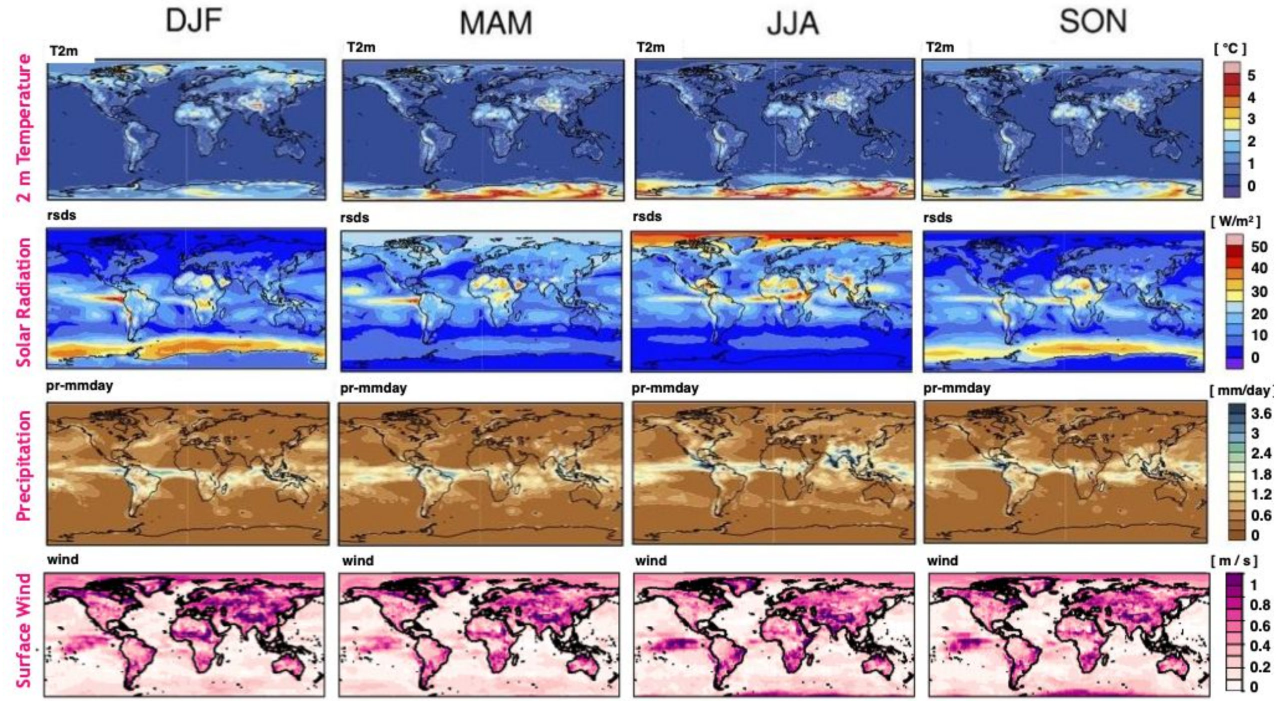
Reanalysis intercomparison



Multi reanalysis spread of seasonal climatological mean 1980-2017 of 2 m Temperature, Solar Radiation Precipitation and Surface Wind.

Climatology

- Temperature: The spread among the reanalysis is higher in locations with fewer assimilated data (i.e. Africa and Poles).
- Solar Radiation: Important disagreement between reanalysis over tropical regions and midlatitudes in Summer.
- Precipitation: Large spread over the ITCZ and midlatitudes lands in Summer.
- Surface Wind: Discrepancies observed for continental regions.

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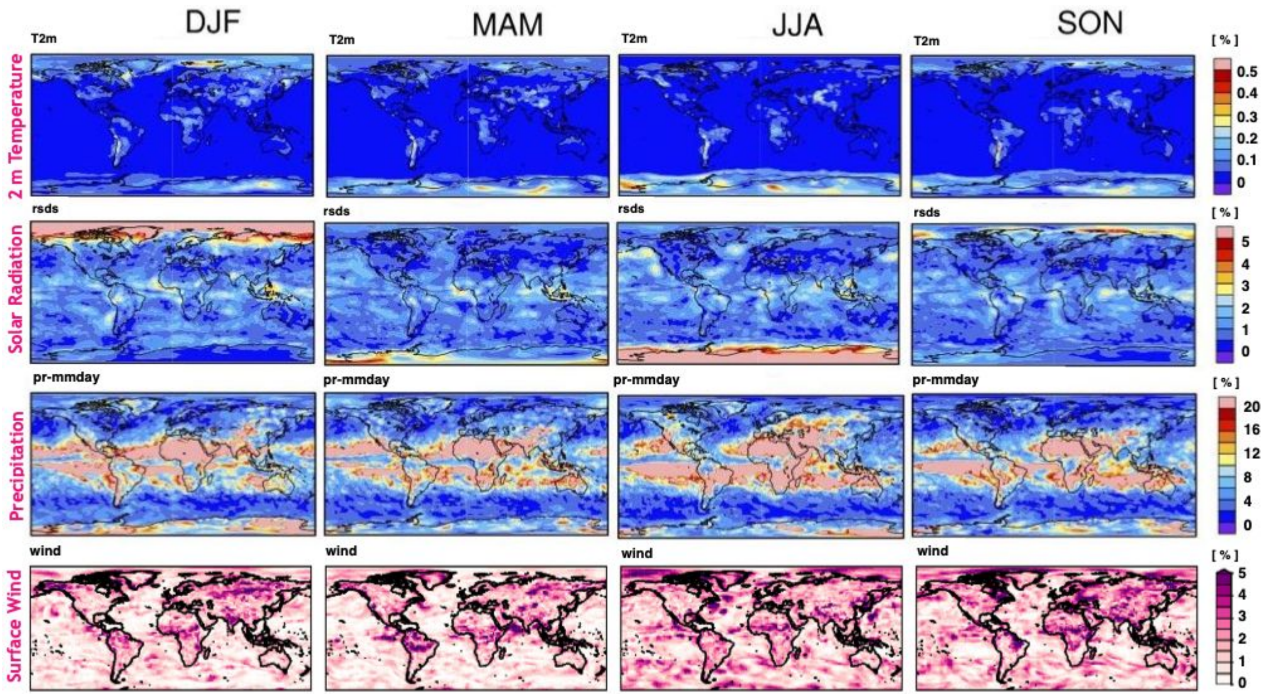
Reanalysis intercomparison



Multi reanalysis spread of seasonal inter annual variability 1980-2017 of 2 m Temperature, Solar Radiation, Precipitation and Surface Wind.

Interannual Variability

- Temperature:Larger spread of variability where the climatology is biased due to scarcity of data assimilated.
- Solar Radiation: High spread among reanalyses where the variability is higher.
- Precipitation: High spread of variability over ITCZ.
- Surface Wind: Important disagreements between reanalyses for both oceans and continents.

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Observations employed for reanalysis verification and benchmarking

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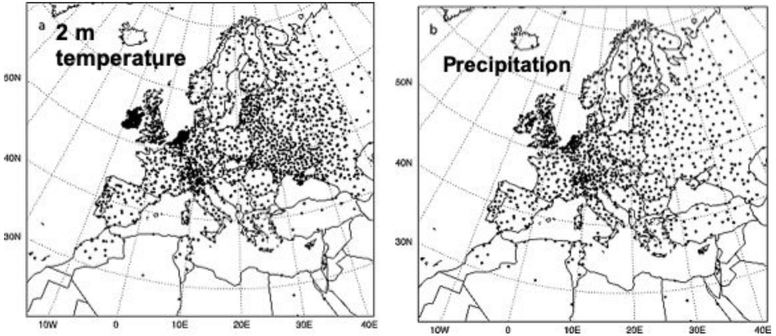
Observational Datasets

Observa-tional Dataset	ECVs	Coverage	Source	Grid	Time resolution	Available period
E-OBS	2 meters temperature	Europe	Meteo stations	Regular 0.22°x0.22°	Daily	1950-2017
	Precipitation					
CMSAF SARAH2	Surface solar radiation downward	Europe & Africa	Satellite	Regular 0.05°x0.05°	Instantaneous, daily & monthly	1983-2015
Tall Tower Database	Surface wind	Global	Instrumented tall towers	Unstructured grid (213 sites)	Sub-daily, daily & monthly	1979-2018

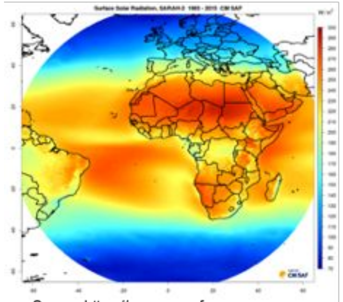
EOBS Stations



Source Haylock. M.R. et al. 2008. JGR113, D20119, doi:10.1029/2008JD1020.

CMSAF SARAH2

Surface solar radiation downward

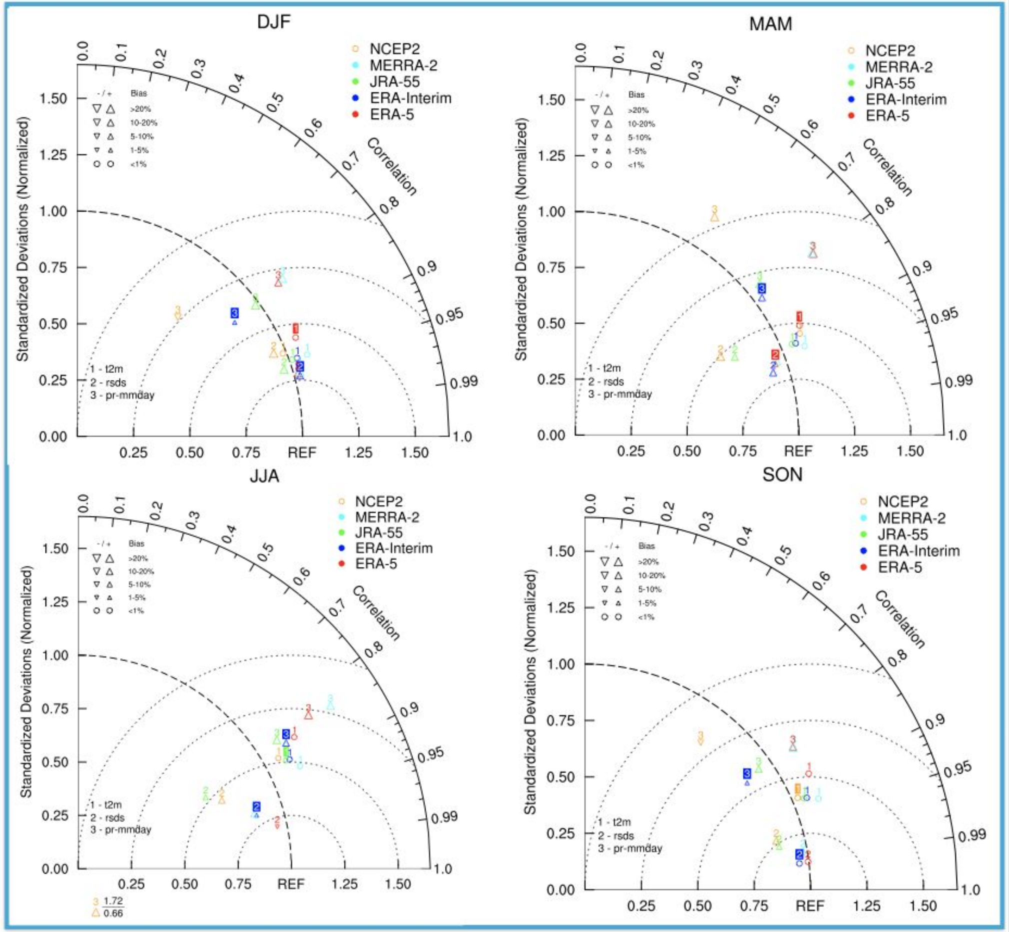


Source https://www.cmsaf.eu

Tall Tower Database

Surface Wind

Verification with in situ and satellite observations



ERA-Interim, JRA-55, MERRA-2 and NCEP-R2 1983-2014. ERA-5 2000-2014

EOBS
&
CMSAF-SARAH2

Taylor Diagrams of monthly

Solar Radiation vs. CMSAF –SARAH2

Temperature and Precipitation vs. EOBS.

Correlation, RMSD, Normalized Standard

Deviations and Bias are evaluated.

Temporal and Spatial verification.

Monthly

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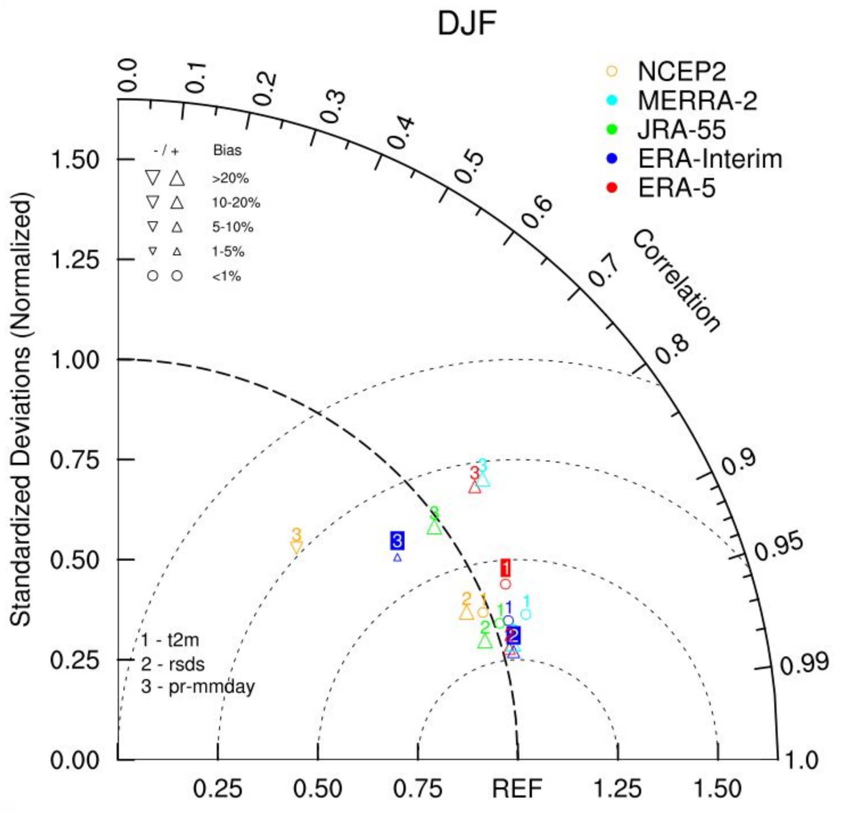
Verification with in situ and satellite observations



Taylor Diagram

A single point on the bidimensional plot indicates the **ratio of the normalized variance** (represented by the normalized ratio of their standard deviations), the **correlation** and the **centered root-mean-square error** between test dataset and reference data set.

Test patterns that agree well with reference pattern will lie near the black dot on the x-axis (REF).

- The standard deviation ratio of the test pattern is proportional to the radial distance from the arc at the point and the arc at the REF.
- The centered root-mean-square error between the test and reference patterns is indicated by the semicircle contours centered on the REF.
- The correlation is given by the azimuthal position of the point.
- The amplitude of the bias is indicated by the dimension of the triangle.

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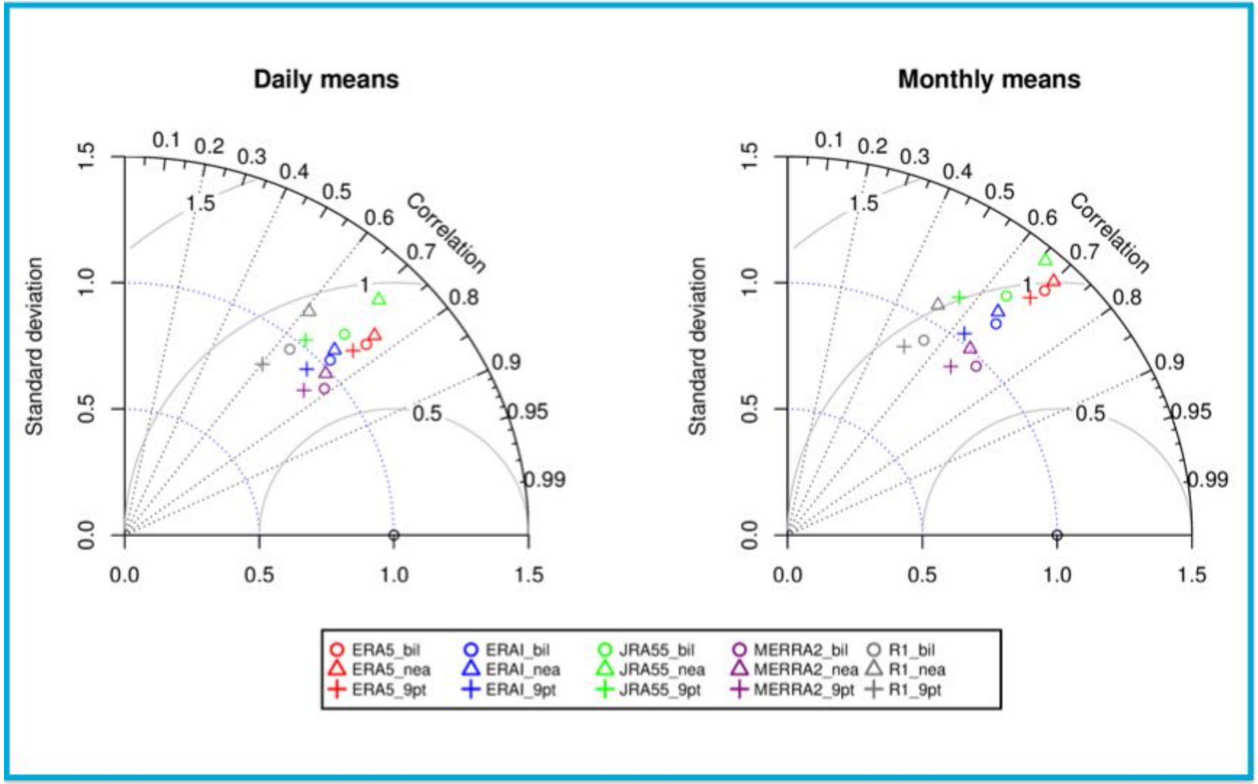
Verification with in situ observations



Monthly & Daily

Tall Tower Database

Taylor Diagrams of monthly and daily surface wind speed.

Correlation, RMSD and Normalized Standard Deviations are evaluated.

Temporal and Spatial verification.

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Which reanalysis is “best” for each subsector?

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Temperature		ERA5	MERRA-2	JRA-55	ERA-Interim	R1 or R2
	Climatology	-**Generally low biased**	-Negative bias in North Europe, North America and North Asia in DJF and SON	-Positive biased in East Antarctica	-Warmer winter bias in Arctic	-Large bias in Africa
	Climatology	The spread among the reanalysis is higher in locations with fewer assimilated data (i.e. Africa and Poles). High correlation in Europe with observed data.				
	IAV	-**Variability comparable to the MM**	-High variability in central Africa and Amazonia	-Small Variability in Antarctica	-High variability in North Europe and Asia	-Too large variability in Africa and polar regions
	IAV	Larger spread of variability where the climatology is biased due to scarcity of data assimilated. Spatio-temporal correlation and variability well performed respect to observed data.				
	Trends	Trend estimates and significance are broadly similar.				

Precipitation		ERA5	MERRA-2	JRA-55	ERA-Interim	R1 or R2
	Climatology	-Negative bias in ITCZ	-Negative bias in ITCZ.	-Positive bias in ITCZ	-Generally negative bias over sea	-Large negative bias over ITCZ
	Climatology	Large spread over the ITCZ and in Summer at mid latitude over land. In Europe, spatial correlation and variability respect to observed data are not always good.				
	IAV	-Too small variability over dry areas	-Mixed pattern of variability over dry areas	-Mixed pattern of variability over dry areas	-Generally too low variability	Generally too large variability
	IAV	High spread of variability over ITCZ. Spatio-temporal correlation and variability not always well performed respect to observed data.				
	Trends	Positive trend over tropical areas. Low significance over continental area of the Northern Hemisphere.				

Solar Radiation		ERA5	MERRA-2	JRA-55	ERA-Interim	R1 or R2
	Climatology	**-Less biased dataset**	-Positive bias over south-eastern Asia during JJA	-High positive bias over storm-track zone of the Southern hemisphere and inland tropical area	-Similar to ERA5 but with stronger bias over Africa (positive) and South-East Asia (negative)	-Generally high positive bias
	Climatology	Important disagreement between reanalysis over tropical regions and mid latitudes in Summer. Good correlation with satellite data over Europe and Africa.				
	IAV	High spread among reanalyses where the interannual variability is higher. Underestimated observed variability over Europe and Africa.				
	Trends		Significative negative trend over oceans	Mixed pattern of positive and negative trend over continents	Strong positive trend in North America and Europe during Summer	-Strong positive trend
	Trends	Broadly common positive trend in the Northern Hemisphere inland.				

Surface wind		ERA5	MERRA-2	JRA-55	ERA-Interim	R1 or R2
	Climatology	**Generally low biased. Negative biases only for elevated areas**	Positive bias inland. Slight negative departures in oceanic areas	Low bias inland	**Similar to ERA5**	Negative bias for polar and tropical regions
	Climatology	Discrepancies observed for continental regions				
	IAV	**Low variability inland**	Mixed pattern. Low variability in Amazonia	High variability within continents. Low IAV offshore	**Similar to ERA5**	Generally low variability. High IAVs only between tropics
	IAV	Important disagreements between reanalyses for both oceans and continents				
	Trends	Not considered	Strong positive trends along the equator	Systematically large and negative trends inland. Spurious correlations	In agreement with MERRA2	Strong trends over the tropics
	Trends	Strong discrepancies among models in most regions. No coincidence with obs for the available sites.				

Summary

- Climatology and variability of assimilated variables present large differences in regions characterized by scarcity of data.

- Forecasted variables show large discrepancies over region where the role of the model parameterizations is more relevant.

- High-resolution reanalyses (i.e. ERA5) are in better agreement with observed data for temperature, solar radiation and wind speed.

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The impact of EuroAtlantic Teleconnections in energy generation and demand over Europe

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Computing EuroAtlantic Teleconnections in S2S4E

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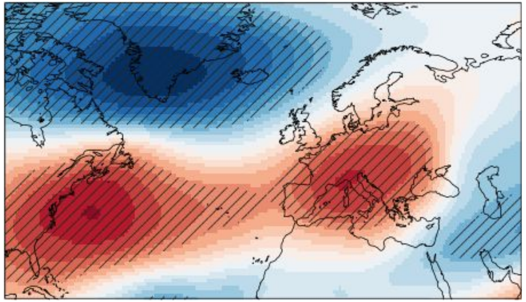
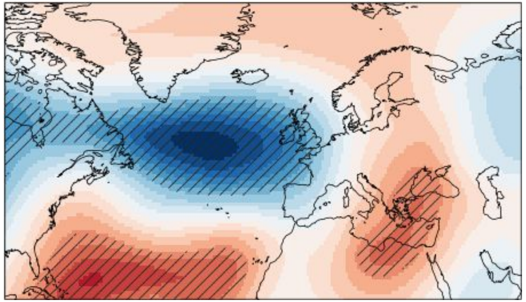
The four main EuroAtlantic Teleconnections:

January patterns

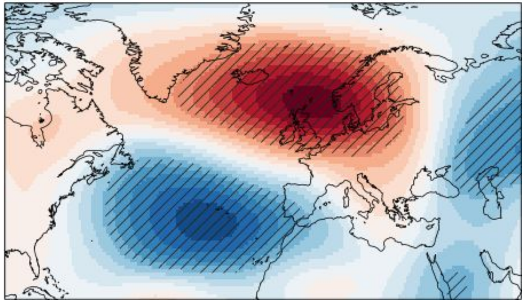
NAO: North Atlantic Oscillation



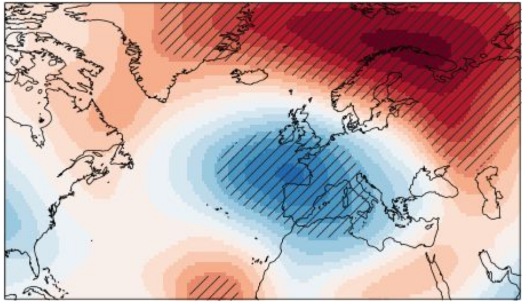
EA: East Atlantic



EAWR: East Atlantic/Western Russia



SCAND: Scandinavian pattern



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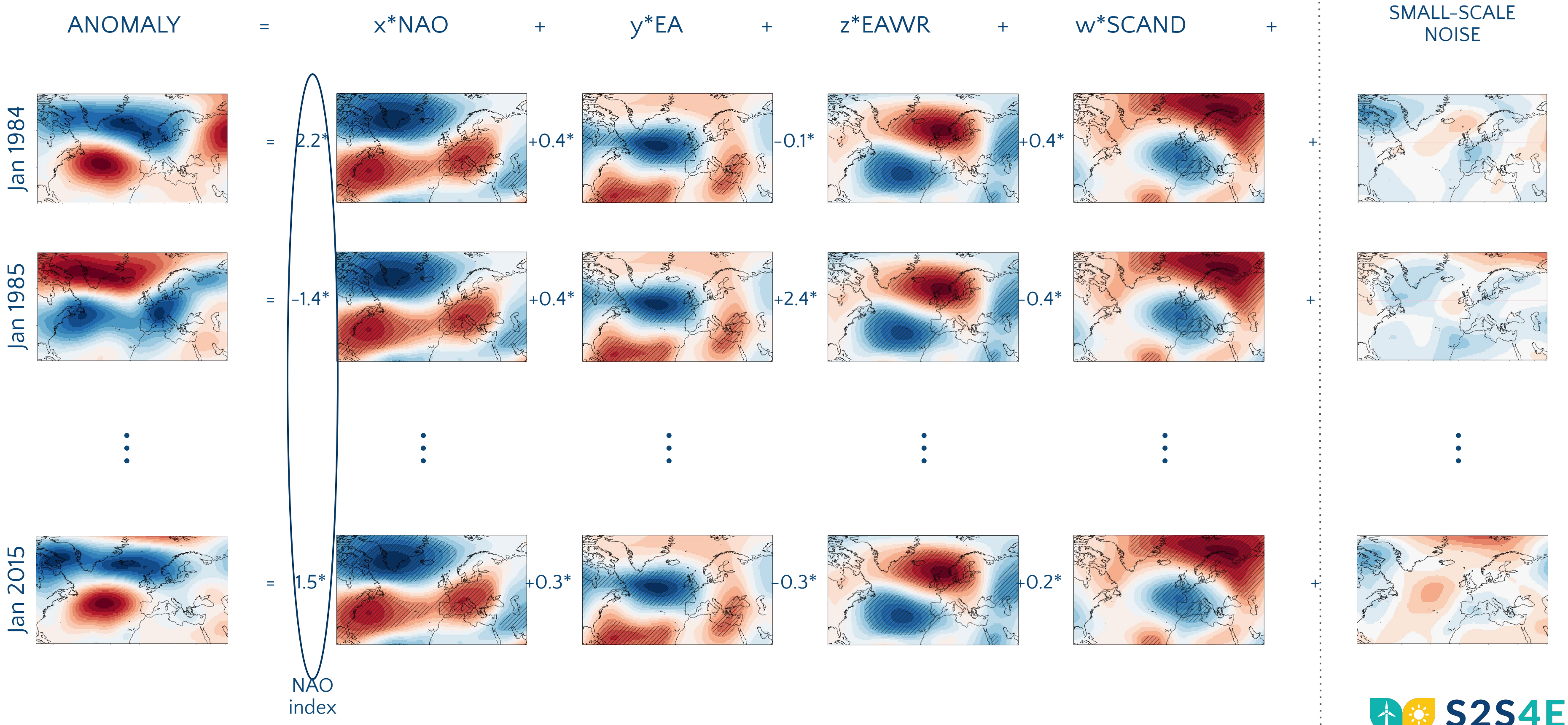
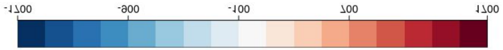
EOF: a tool for dimensionality reduction





Note: some concepts have been simplified for clarity, for instance the scaling of the indices.

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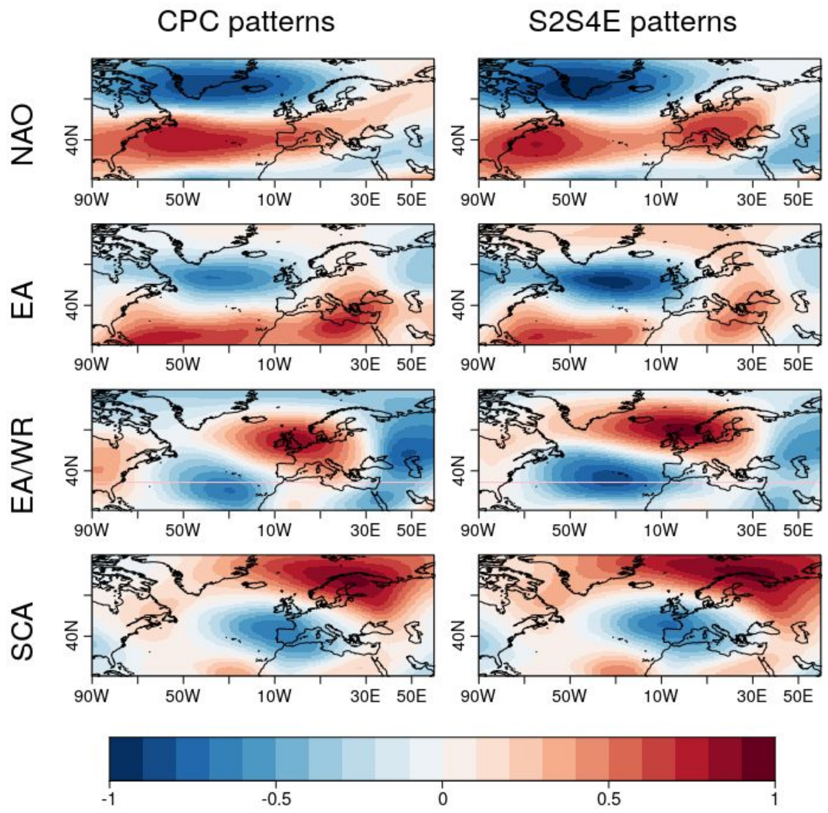
Replicating CPC results



Methodology details

- *Variable*: monthly anomalies of geopotential height at 500 hPa
- *Source*: ERA-interim
- *Period*: 1981-2016
- *Region*: 90W-60E and 20-80N
- *Method*: Rotated EOF with varimax rotation, retaining 4 EOF modes.
- *Timescale*: monthly (seasonal)
- *Transitions*: for each month, the monthly anomalies of the previous and next month are also included in the REOF analysis, although only the index for the central month is used.

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Evaluate EATC impacts on Energy generation and demand

- ECVs:
  - wind
  - temperature
  - solar radiation
  - precipitation
- Energy Indicators:
  - wind capacity factor
  - solar capacity factor
  - energy demand at country level

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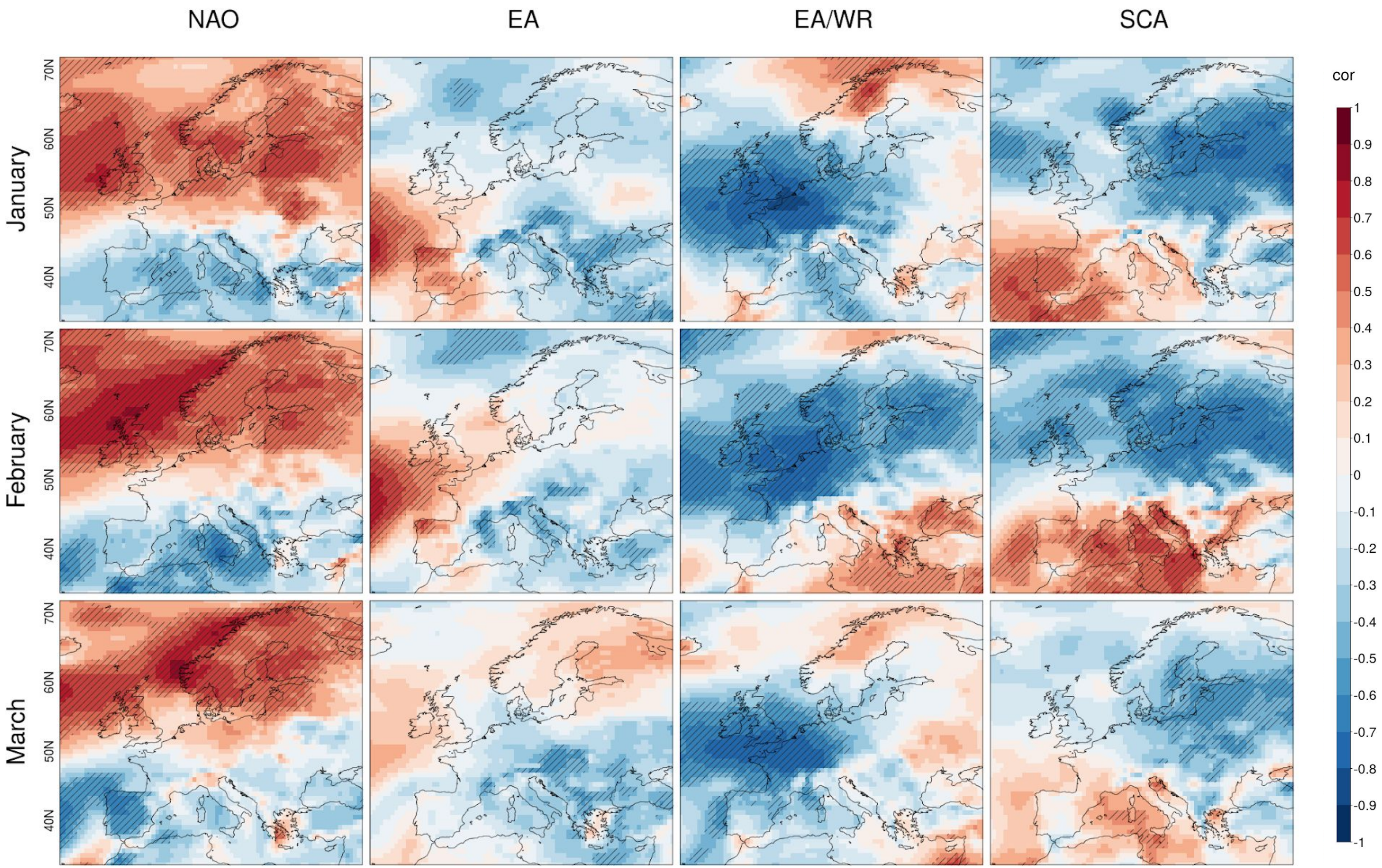
Correlation with surface wind



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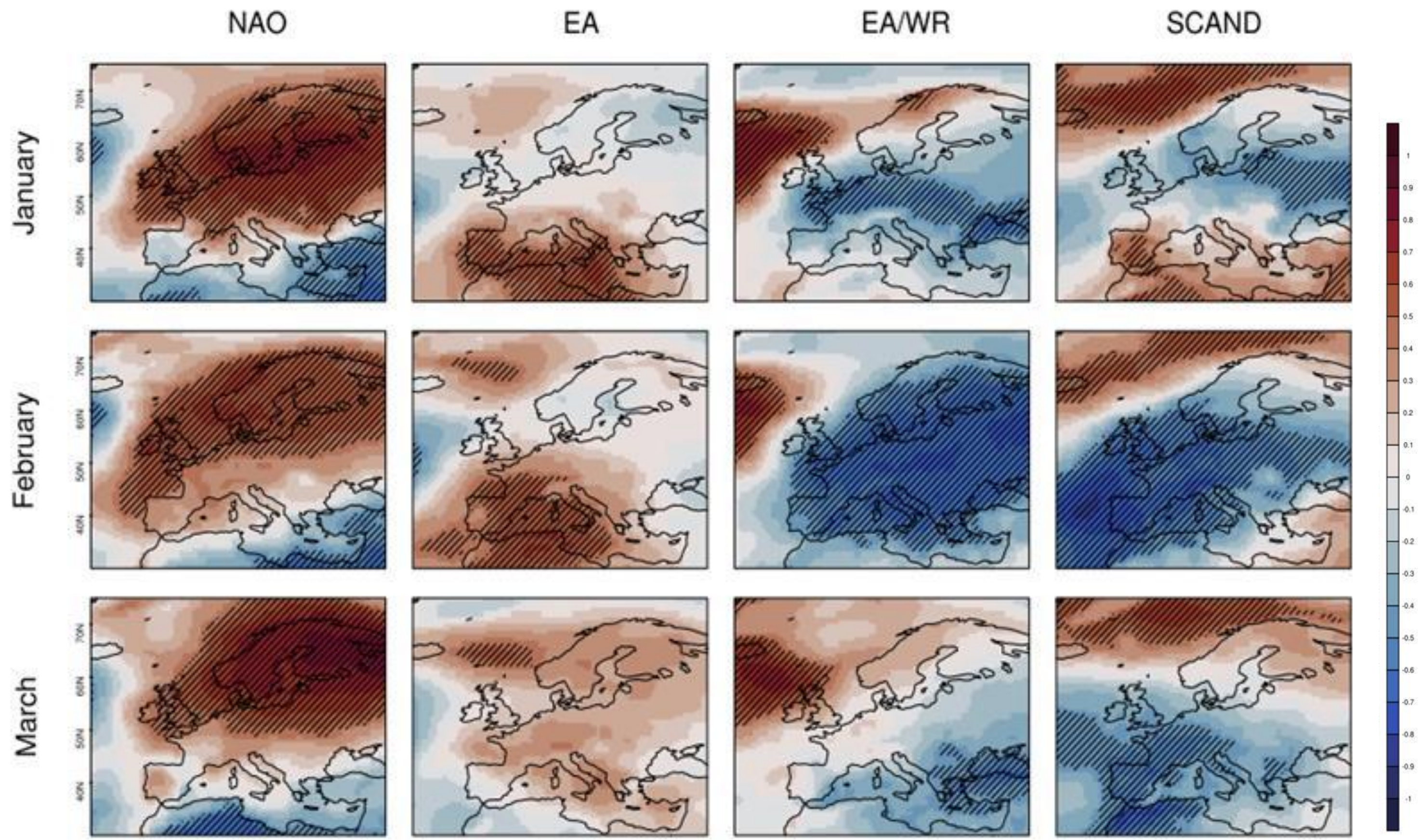
Correlation with 2m temperature



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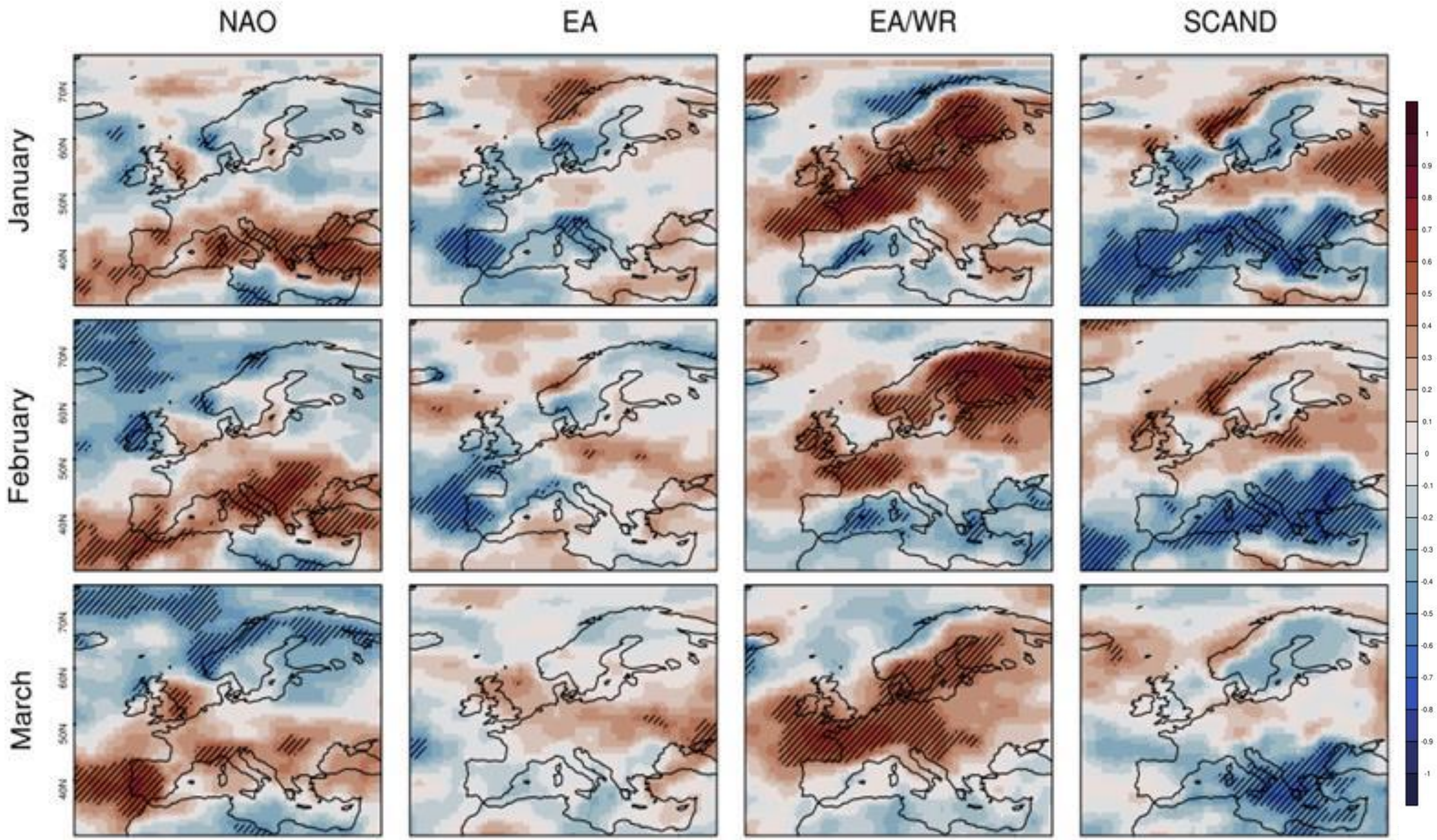
Correlation with solar radiation



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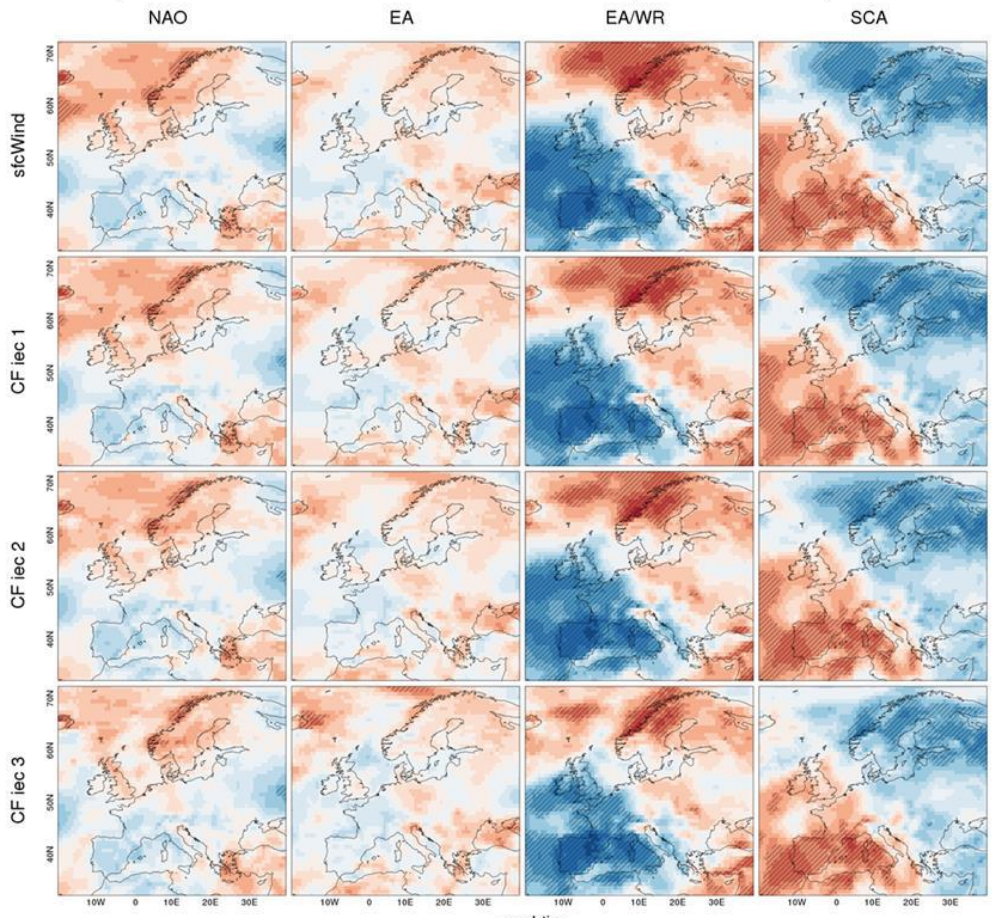
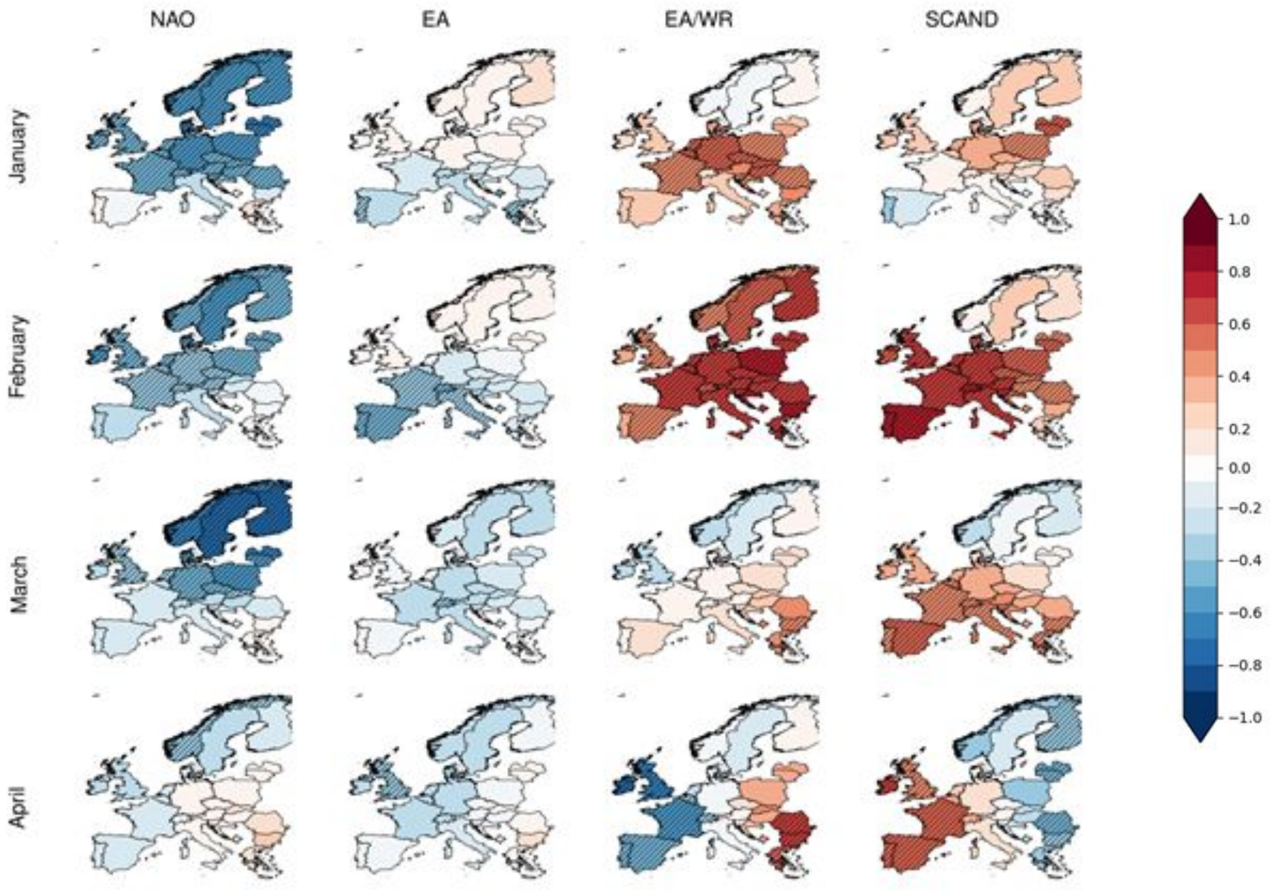
Correlation with wind capacity factors

Impact in April



Correlation with energy demand



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Main conclusions:

- Areas of influence of the four EATC change month by month
- Different impacts for different sub-sectors
- NAO alone is not enough to describe impacts
- Asymmetric impacts not described

Ongoing research (WP4):

- Can we predict NAO, EA, SCAN months in advance?
- If so, can we use that to enhance energy predictions?

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Weather Regimes Over Europe

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Outline

- Methodologies for computing EuroAtlantic weather regimes
- Impacts of the weather regimes on essential climate variables
- Impacts of the weather regimes on energy indicators
- Can we use weather regimes to predict energy indicators at sub-seasonal timescales?

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What is a weather regime?

- A WR is a large scale pattern of atmospheric variability.
- WR's represent gross states of the atmosphere, which change on the time-scale of days-weeks.
- A WR is created by grouping meteorological features into a number of categories. (four for the Euro-Atlantic region)
- WR's are commonly calculated using machine learning techniques.

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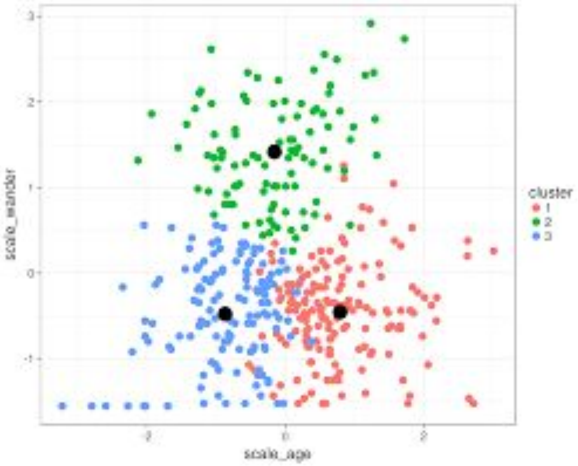
Computing EuroAtlantic Weather regimes

- ERA-interim data 1981-2016
- Euro-Atlantic region (27°-81°N, 85.5° W-45°E)
- Daily-mean MSLP anomalies (climatology filtered to remove short-term variability)
- Weight the gridded MSLP by cosine of latitude (to give an equal area weighting to each gridbox)
- K-means cluster the data for each month into 4 clusters.



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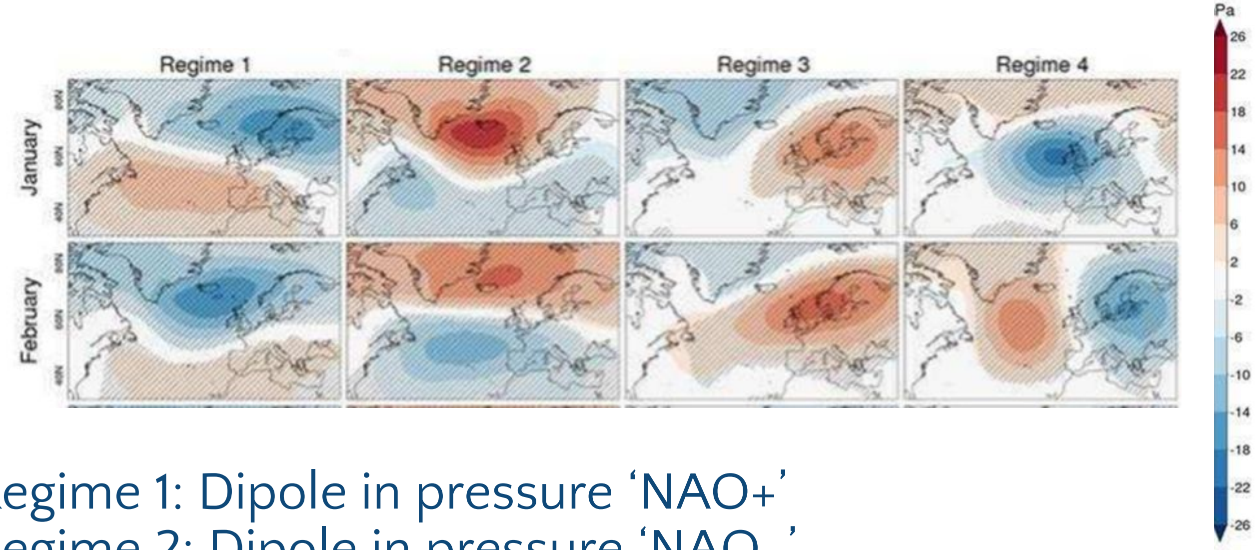
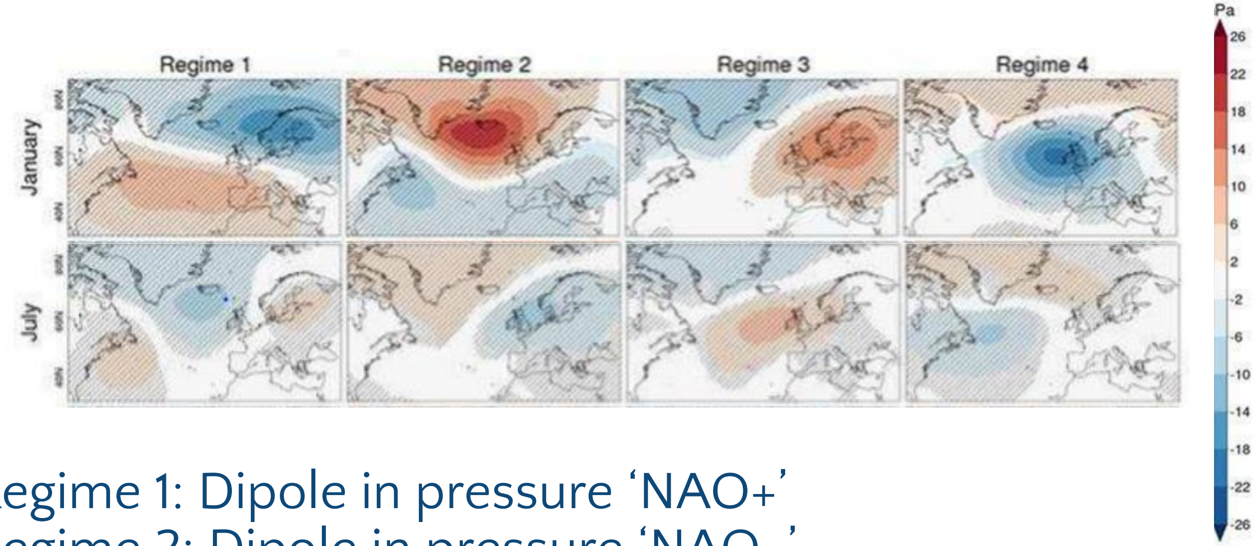
EuroAtlantic Weather regimes:



- Regime 1: Dipole in pressure ‘NAO+’
- Regime 2: Dipole in pressure ‘NAO–’
- Regime 3: High pressure over Scandinavia
- Regime 4: Low pressure over central Europe (varies a lot through the months)

EuroAtlantic Weather regimes:



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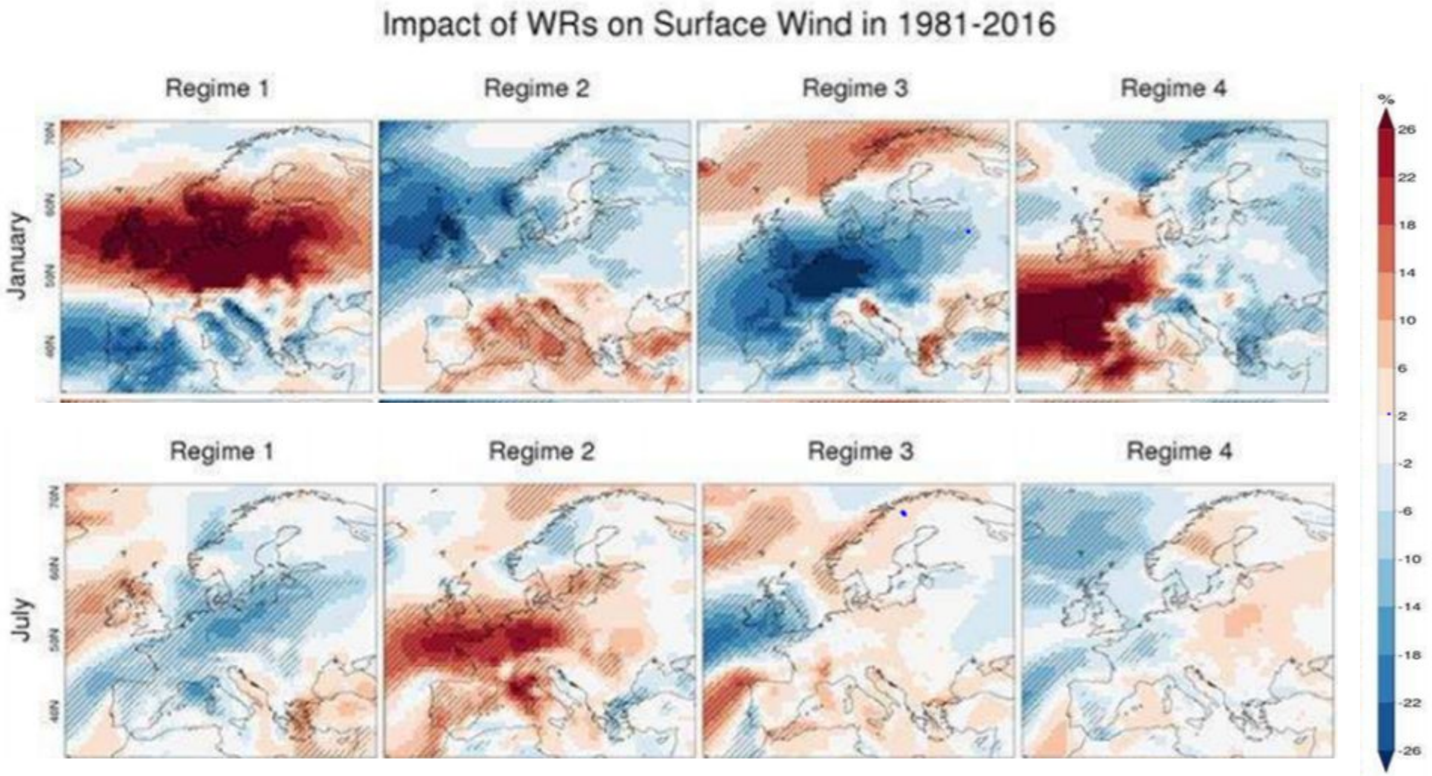
- Regime 3: High pressure over Scandinavia
- Regime 4: Low pressure over central Europe (varies a lot through the months)

Impacts of Weather regimes on surface winds



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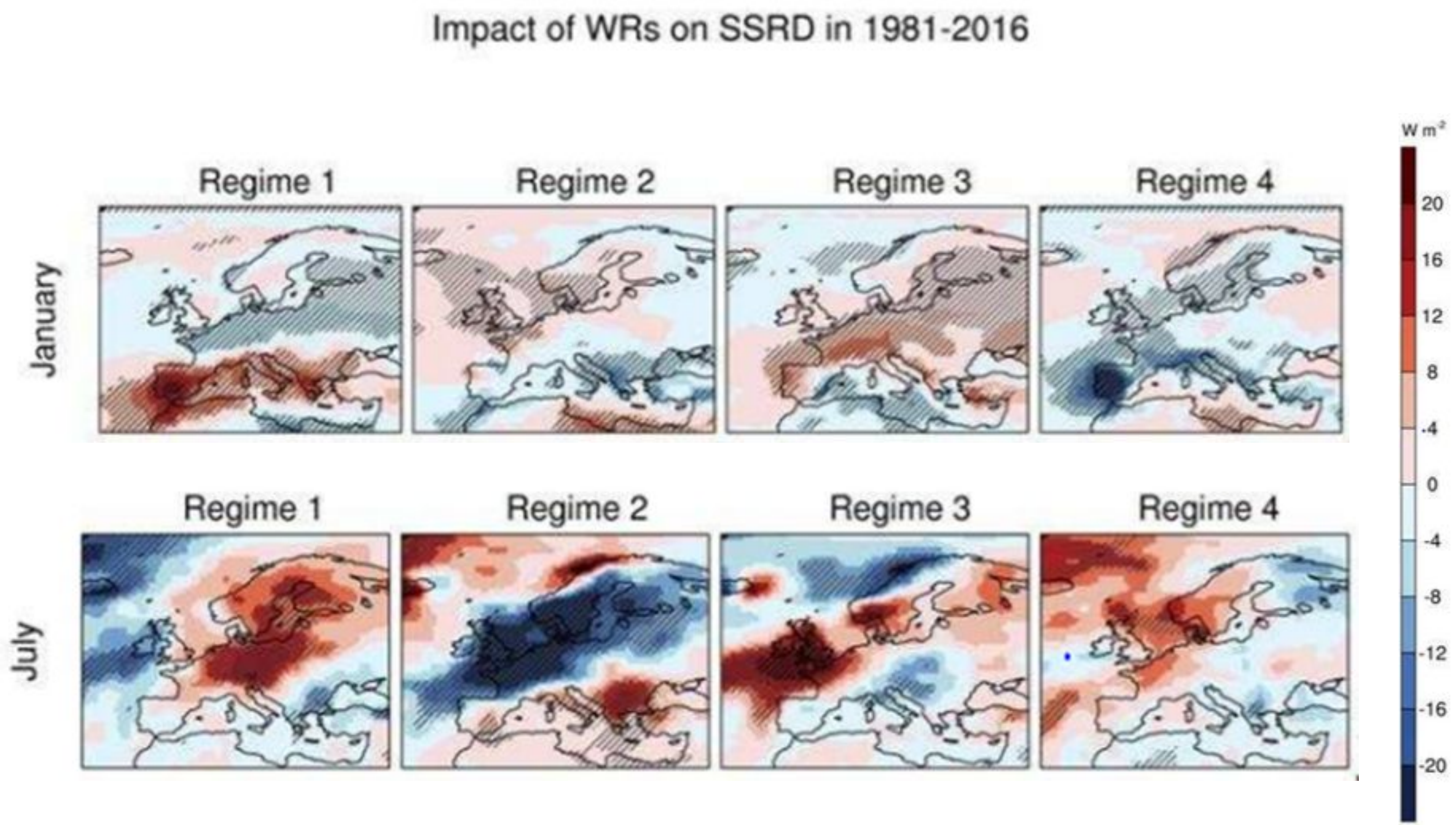
Impacts of Weather regimes on surface radiation



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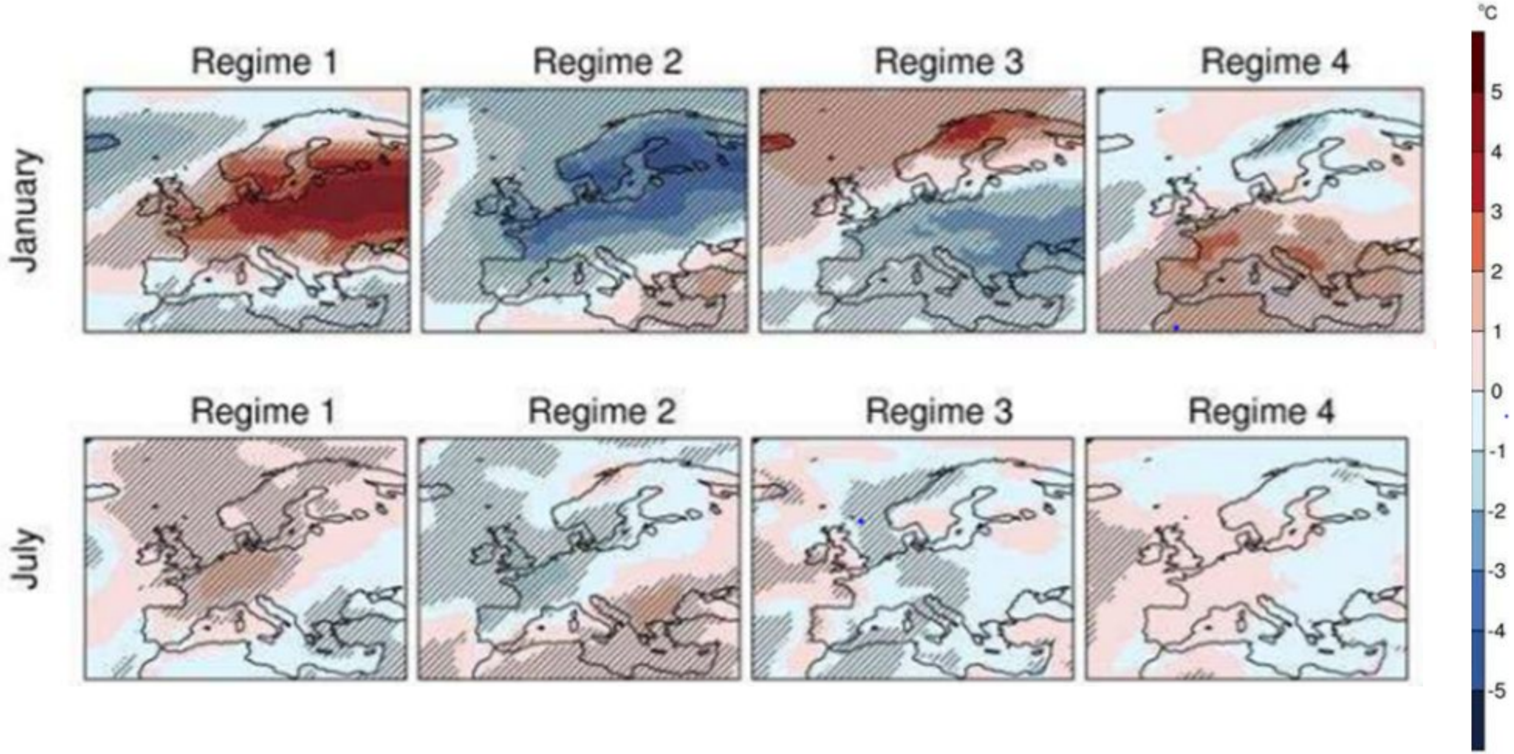
Impacts of Weather regimes on Temperature



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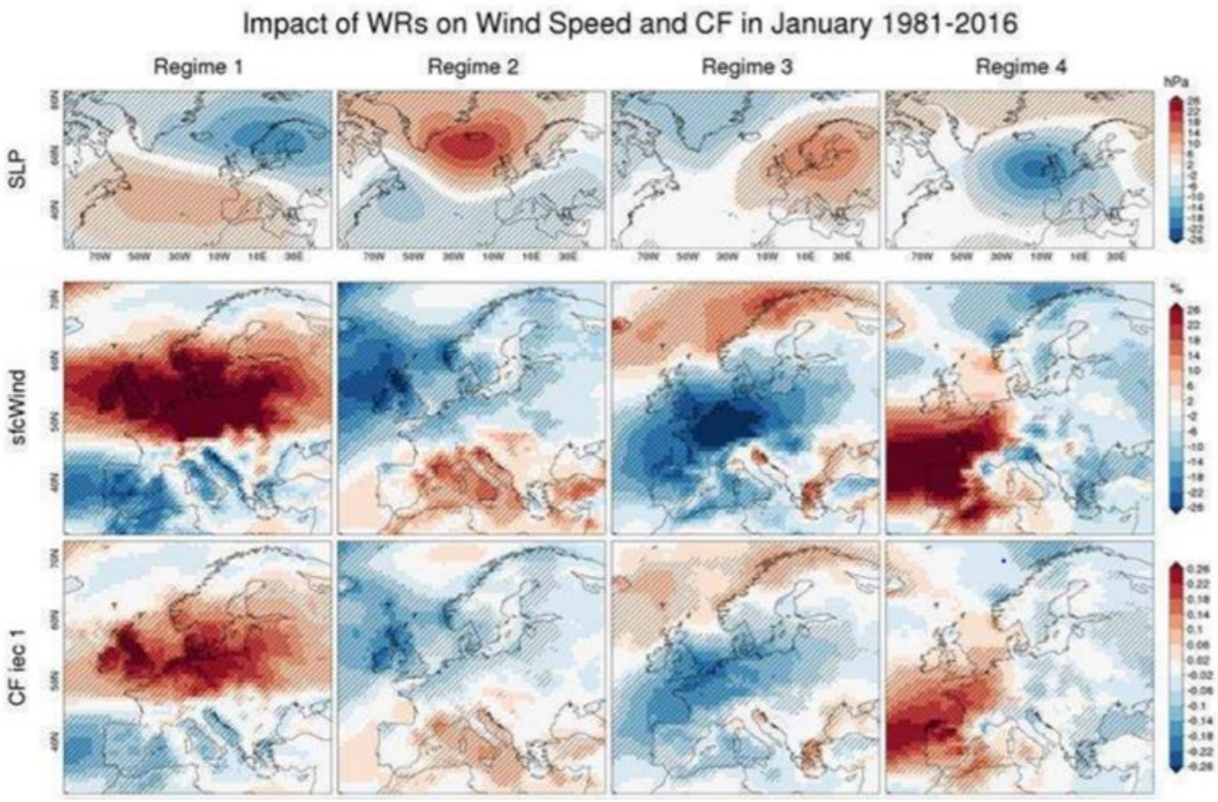
Impacts of Weather regimes on Wind Power CF



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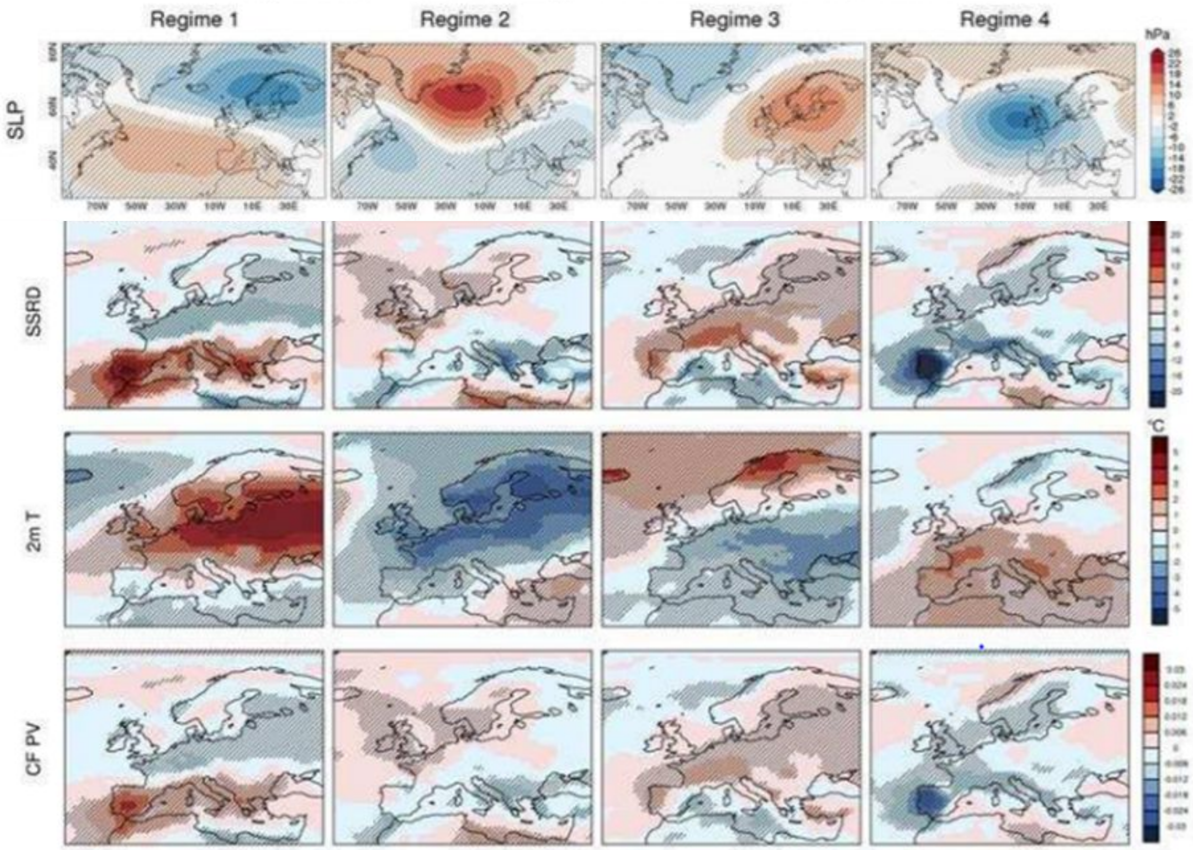
Impacts of Weather regimes on Solar Power CF



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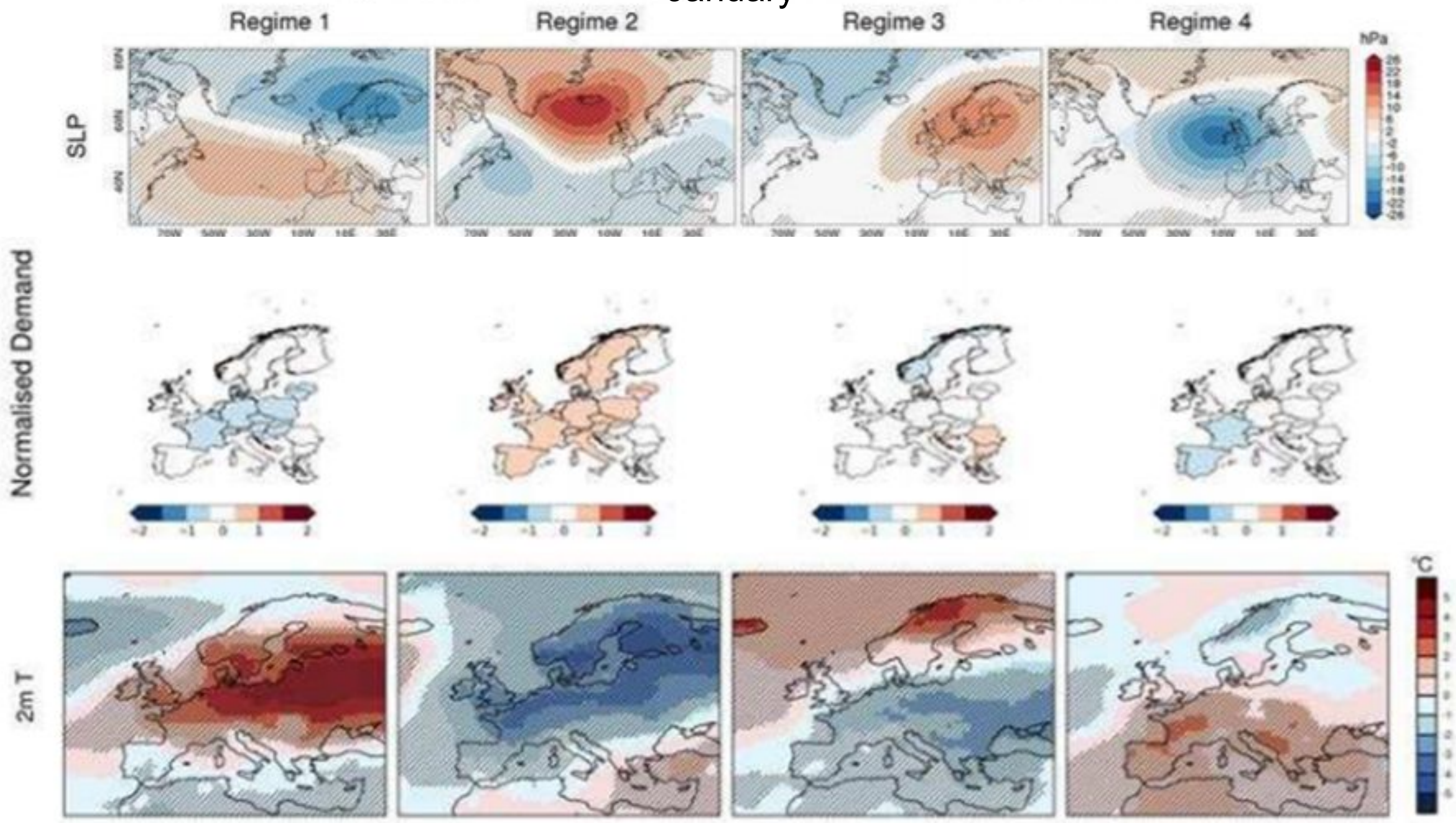
Impacts of Weather regimes on Demand

January



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Summary

- A methodology has been developed to calculate WRs for each month from filtered MSLP data.
- WRs can significantly influence ECV's and energy indicators, especially in winter months.
- The spatial impact patterns of WRs 1 and 2 often exhibit a bipolar structure with a mostly north-south gradient similar to the NAO.

- Future work will investigate the predictability of these regimes in sub-seasonal forecasts, and if this information can improve energy indicator predictions.
- This presentation has shown the highlights of D3.2, see the document for more information (available on the wiki).

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